

ORIGINAL RESEARCH ARTICLE

Changing the Spanish arts curriculum for secondary school: the case for digital geometry and screencasting

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The classroom curriculum for teaching geometry using digital technology needs to emphasise a radically different set of contents and skills when compared with the current paper and pencil standards in use in Spanish classrooms complying with the current official curriculum. This research examined possible applications of vector graphics and screencasting as the main tools to teach digital drawing and geometry in secondary school classrooms during the year 2018–19 within the limits set in the official curriculum, intending to find out how ready students are to use these digital tools. In collaboration with art teachers in Madrid, a screencasting set of seven lessons were made available to almost 250 students and feedback data were collected using an online survey. An analysis of the results revealed that no technological or cultural barrier to adoption existed on the part of the students to accept both online instruction methods, and digital geometry and drawing exercises with vector graphics. Based on these findings, contextual information is presented to advocate Spanish educational policy decision-makers to encourage the use of Information and Communication Technology (ICT) in classrooms in a well-adapted, environmentally-conscious manner.

Keywords: empirical; quantitative; technology; digital literacy; secondary education; digital geometry

Introduction

Framing the problem

Economic and technological changes driven by increasing globalisation are impacting education systems around the world. Learning is being reshaped by these changes at a much faster pace than our cultural institutions, our school systems especially, can keep up with. Trying to keep up with the evolving panorama can be a bewildering experience. The fast obsolescence rate of digital applications, new methodologies and the rate at which novel buzzwords are born and dead have had a deterrent effect on down to top change settling into system reforms. Amidst the rush of the new and the inert stasis of old teaching methods, we still need to make sure that we exploit

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new technological possibilities in a way that will maximally enhance their educational potential (Reimers and McGinn 1997). Ideally, this process would further recuperate our understanding of the ways 'that knowledge itself is mediated by the computer presence' (Noss 2013) and the ways that new representational forms can reformulate knowledge disciplines (Wilensky and Papert 2010) if we are to surf these waves of change without losing balance. Digital drawing and digital geometry are good examples of how this globalised digital changes are colliding with traditional schooling in a field where knowledge is mediated by computer with new representational forms reformulating the discipline. Most professional activities around image creation, editing and publishing require specialised digital skills and it has been increasingly so for some decades now. All professional applications of geometry are digitally mediated and digitally enhanced to the point where building structures could not be calculated without computers, form-finding and personalisation of products could not range as they do, simulations of complex systems could not be rehearsed and applied to industrial design, data visualisation and movie making, and animation features could not be rendered as they are. In contrast, the use of traditional paper and pencil geometrical techniques has vanished from professional practice. Meanwhile, secondary school arts curriculum in Spain devotes one-third of the ever decreasing time for visual arts (every reform of the many written into law in the past years has reduced it) to teaching ruler and compass geometry skills on paper, building towards an accumulative training from first grade to the EVAU (Evaluación para el Acceso a la Universidad) test, in which geometry as technical drawing counts in an elective subtest required to access technical studies such as architecture, engineering or fine arts.

In the international context, educational research experiences the same transformative globalisation, with organisations such as OECD (Organization for Economic Co-operation and Development) taking the lead of data gathering and influencing governments all around the globe but PISA (Program for International Student Assessment) is not only a dataset, when looked at from the perspective of digital geometry in secondary school classrooms, some features of their activity arise as preconceptions sustaining practices that preclude change. A prevalent reliance on the 'three Rs' (formerly reading, writing and arithmetic, but rapidly becoming reading, writing and robots) when measuring educational outcomes, the still common use of paper technology in classrooms, and the continued mainstream discourse depicting the inexorability of integration of markets, nation-states and technologies (Rizvi and Lingard 2009) are examples of distorting factors that afflict educational research projects that try to predict the future success of school students based on the test scores of 15-year-old students (Meyer 2014; Zhao 2015). The PISA programme and its influential dataset provide relevant background to the present research project, both as an impetus to thoroughly analyse the extensive data that can be found on various OECD programmes conducted in Madrid, and to counteract the use of biased digital literacy definitions, and ranking systems that generate more noise than understanding. Bawden (2008) provides an important further discussion about how digital literacy research can define relevant trends in understanding the role the arts, drawing, geometry and images play in the schooling of future literate adults prepared for new times. The lineage of media literacy studies (Buckingham 2008), the cultural practices of remixing typical of the visual arts pedagogy (Ertsad 2008) and how literacy engages cognitive and cultural complex skills 'mastering ideas, not keystrokes' (Gilster 1997) are some of the issues addressed in this volume that are relevant to the present study. Throughout the volume, the idea of the typographic centred academic culture losing the podium of literacy to a pool of digitally-augmented skills and subcultures is present, as a subtheme for policy analysis, cognitive taxonomies and case scenarios.

The need for the present research was also highlighted by recent policy changes, such as the introduction of programming and robotics into the curriculum by the regional government in Madrid and a reduction in the amount of time devoted to arts by the application of the last national reform on education (LOMCE).

Screencasting

From its inception, research on e-learning has found that it benefits students by enhancing time and space flexibility, student autonomy and increased access to educational content and experts (Zhang *et al.* 2006).

Screencasting is a subclass of video that uses computer screens to explain the use of software, relying on filmed demonstrations as the main output. As with any video, it can be replayed as many times as wished, over its whole length or concrete segments. It is a powerful educational tool that can promote autonomy and facilitate personalised attention. Moreover, it is the preferred tool for training in many informal software academies. The emergence of screencast for gamers on YouTube is an example of its reach and its impact on teens, in those places where access and use of the internet has reached most homes such as in Madrid. Although research on the integration of screencasting in a formal educational context is sparse, a general review and discussion of the tool applied to delivering lectures and providing feedback in educational contexts can be found in Kilickaya (2016). A screencasting checklist and instructional strategies are available in Sugar, Brown, and Luterbach (2010), which may be used by online instructors and instructional designers to develop and assess their screencasts. Well-grounded suggestions that screencasting may promote self-efficacy among students are part of the research presented in Green, Pinder-Grover, and Millunchick (2012). On effectiveness and engagement, the work of Morris and Chikwa (2014) can frame the debate around knowledge acquisition using screencasts. Specific applications have included math teaching for children (Thomas 2017), undergraduate teaching of research design (Carter, Hamilton and Thompson 2017): of social studies (Snyder, Paska, and Besozzi 2014), of statistics (Lloyd and Robertson 2012) and as an instructional technique in libraries (Brown-Sica, Sobel, and Pan 2009; Ergood, Padron, and Rebar 2012).

In the context of artistic training, where traditionally instructional methods rely on experience first, watching and mimicking gestures to acquire dexterity, and apprentice to mentor relation to build on to explicitness and metacognition as a result of reflective practice (Schön 1983), the use of screencasting fits as a continuity of methodology. It is not part of this study to look at the relation these instructional methods may have with the promotion of creativity but in avoidance of critics characterising screencasting as just video watching where informational gain may be attained but no skills acquisition can be transferred, the scene of the teacher showing how to draw and the student copying the drawing as it has been part of the artistic tradition for centuries, both in eastern and western heritage, must be kept in mind. In this sense, screencasting is a video with aspects of blog, of visual tutorial and master class, depending on how it is designed and the role the author chooses to play. Screencasting can be a source of skill acquisition in the context of tool-use actions as explained by Emanuelle Reynaud in 'To watch is to work' (Reynaud *et al.* 2019), where conclusions are that the process of watching intently as another uses a tool can entail a transmission

of cognitive skills. The artistic field, not centred on textual and explicit information, is linked to the development of technology and culture, in ways that may not have been favoured much by the academical tribe. But if causal understanding is not necessary for the improvement of culturally evolving technology (Derex *et al.* 2019), much of the debate around skills and cognition in defining digital literacy (Bawden 2008) may have to take into account this image-related, atelier-borne instructional techniques.

The promotion of autonomy as the enabling phenomena to pursue intrinsic motivated, self-guided learning at a personal pace is also a recurrent trait of the artistic instructional method, a trait also shared by most online learning, as many studies keep concluding (FitzGerald *et al.* 2018; Panigrahi, Srivastava, and Sharma 2018).

These aspects of screencasting and the nature of vector graphics as a building block of digital image and therefore of web communication are intertwined in the acquisition of cognitive skills as much as the geometric concepts and drawings itself. A detailed taxonomy of cognitive skills in the context of functional internet literacy can be found in Johnson (2008).

Vector graphic editors/development of hypotheses

The impact of digital technology on schools can be analysed at the three different functional levels it is being implemented at in schools around the globe: technology applied to school managing and administration, technology applied to teaching and classroom management and technology that is instrumental for students' learning (Zhao and Frank 2003). In the hierarchical chain from the politicians to the administrators to the teachers and to the students, the last node may have been the least influential in the decision making process (Loveless 1996). The quick obsolesce of many programming languages and other digital tools have made it very hard to strategically choose digital literacy tools that are required from the point of view of the students (Walk 2011). In most cases, the pattern of adoption of devices, connections and speacialised software has depended on the market as the agent of introduction, except in a very few places where schools and libraries have taken the lead (OECD 2011). Research on technology and education has focused on instruction and learning technology (Zawacki-Richter and Latchem 2018), obviating instrumental use of computers as field enhancers. All these factors can explain partly 'why aren't computers used more in schools' even 20 years after Loveless (1996) first asked it, and how schools disrupt technology, and not the other way around, as Papert (1997) concluded.

To that general panorama, we must add the peculiarities of the visual disciplines as they are being taught at school. Art-related disciplines are not at the centre of educational technology research; the relation between ICT and learning is referenced to reading text, math and science in the PISA reports (OECD 2011). Drawing skills have never been part of a PISA test, until the drafts for the 'Creative Thinking Framework for PISA 2021' included examples of digital drawing for the visual expression domain units proposed. These drafts and the CERI project 'fostering and assessing creativity and critical thinking skills' include art as a domain of creativity, alongside maths, science and text, with a discussion of creative engagement that addresses empathy, 'hands-on' and performative aspects of the art sphere. Other OCDE publications are centred on technology uses in school such as 'Students, Computers and Learning. Making the connexion' (OCDE 2015), where again a stress is made that basic literacy and numeracy skills are needed and no mention of art, drawing or geometry can be found. These siloed conversations are a usual finding in the specialised literature that seems to keep technology and art apart. Geometry is also taught at secondary schools from the mathematical approach, where research on specialised computer environments for learning geometry can be found (Clements and Battista 1994), especially significant to those related to the logo movement advocated in the mid-1980 by Seymour Papert. Even then, a closer examination of the Logo Foundation repository (Logo Foundation, n.d.) reveals that his research is mostly related to programming and coding, and less to geometry teaching.

It is from the fields of technological, engineering and architectural higher education that calls to change the geometry curriculum (Iordanova 2007) and to include technological trajectories in technological literacy criteria that pertain to computational geometry and the skills needed to master them (Walk 2012) are arising. Although these are centred on engineering studies, many of the arguments apply equally to choosing the right tools to include technological literacy with geometry in the arts.

The fact that arts and technology are being kept as 'siloed conversations' in the field of teacher education has also been previously pointed out (Jensen 2016). This may reflect a cultural trend to present art and technology as two ends of a rationality arch that would require further research on teachers' beliefs and attitudes to be confirmed but it is outside the scope of the present work.

At present, we choose to centre our gaze on the students, to put to test their readiness to the use of vector graphics in the art classes. Given the pervasive use of vector graphics in all art-related industrial professions, as the basis upon which many software tools currently are – and will likely continue to be – developed, given the present possibilities of internet as a commodity and the abundance of free software, given the role that image can play in media or digital literacy, we expect students will pose no barriers to the use of vector graphics software and screencasting instructions in secondary school art classes in Madrid. We hypothesise that students have enough digital culture and literacy and they are thus ready to accept and benefit from screencasting and vector graphics as part of their learning experience in the art classes.

The three major research questions of this study are 'Is there any barrier from the students' point of view preventing the widespread use of vector graphics as the main tool to teach geometry, once the required technology and culture are in place?', 'How does the use of vector graphic technology affect the autonomy, active participation and perceived relevance of learning activities, and does this depend on the sources of information, the curriculum, how students learn and how these technologies are made available?' and 'Is it right to think of digital geometry and screencasting as social-ly-pervasive tools that students can understand and accept directly?'

Methods

Research design

This study engaged secondary art teachers in a screencasting project that tutored students to draw a geometrical pattern or an animated line drawing (gif). An open-source and freely-available vector graphics editor, Inkscape, was used as the main drawing tool. The experimental design included two groups: *control* and *experiment*. *Control* group was not exposed to the instructional materials while *experiment* group used them in class with their teachers. Both groups were given a task and surveyed to evaluate several aspects of their performance in connection with the instructional materials.

Art teachers active in the secondary school system were approached through their professional associations and calls to participate were placed in twitter accounts and mailing lists of ongoing projects, the institutional webpage of the author and via word-of-mouth. Initially, 15 positive answers to participate were received. Participation was voluntary; there were no payments or other professional credits given to participants.

After studying the official curriculum that states the required contents, skills and learning standards for art (Educación plástica, visual y audiovisual) in the region of Madrid (DECRETO 48/2015, de 14 de mayo, del Consejo de Gobierno, por el que se establece para la Comunidad de Madrid el currículo de la Educación Secundaria Obligatoria 2015), two playlists of videos were produced with the screencasting technique. The first playlist contained four videos that instruct on how to sequentially draw an animation in gif format using Bezier curves in Inkscape. The second playlist produced was a series of three videos with instructions on how to draw and repeat a classical geometrical pattern known as the Nazari bow tie (from the Alhambra decorative program) with the required precision. Both playlists shared a 10-min-long first chapter in which basic instructions on how to download and install the vector graphics editor - Inkscape - was provided. In the geometrical pattern playlists, the longest video was the final one playing for 12:30 min and the shortest and middle ones were each 9 min long. The animation playlist videos were around 10 min long, except for the final chapter that had a duration of 14:08 min.

Both playlists were presented to the teachers in advance of the beginning of the school year, and comments and feedback were encouraged. The participating teachers were asked to use the material as part of their classroom schedule and to assess the programme in the most suitable manner each teacher could devise. The playlists were made available online on a Youtube channel (Sáez Lacave 2018a, 2018b) created for this research project and on the institutional website provided to the school community by the regional government (https://www.educa2.madrid.org/educamadrid/). The only temporal restriction given was the need to answer the final surveys, one for teachers and another for students, during the last term of the school year (before leaving for summer vacation). All communication took place via email and no face-to-face meetings were required.

Sample

The first activity required of participants was a survey, in which teachers had to declare the number of groups and size of classrooms, the technology available, their previous experience with the technology and their content choices, as well as other general identification information. In this early stage, some participants dropped out due to lack of the required technological environment at the school, lack of opportunity to carry out the requested activities or due to personal misfortunes. Some teachers were approached and asked to restrain from using the materials with half of their groups, when they had at least two, thus acting as a control group for the research. Participation was at all times voluntary. At the end of the school year, an anonymised version of the final survey was made available to all participants. A total of three schools (one teacher at each) participated to the end in this project. A group of 37 students from one of the schools participating with several groups acted as control and did not know the instructional material. Our sample was compiled from the answers received from the three teachers and their students and consisted of responses from 247 students in total: 144 from the first year of Secondary education (ESO), born in 2002/03, and 103 enrolled in the second year of ESO (13 years of age). Teachers participating in this research were from the IES Satafi in Getafe, IES Las Rozas1 in Las Rozas and Colegio Blanca de Castilla in Madrid. The three centres have technological programmes of similar sophistication, with the open-source learning programme moodle available and with computers and internet connectivity available both at school and at home. Further characteristics such as gender statistics, students' academic performance, socioeconomic environment and so on were not used in the analyses but can be retrieved from data in OECD PISA.

Data collection instruments

The data collection took place through an anonymous web-based survey administered in May and June of 2018 to students in the three participant schools in the region of Madrid, Spain. Students completed this anonymous survey independently while at school during proctored sessions. The survey assessed the acquisition of a set of skills, knowledge and digital savvy via multiple-choice questions and tasks. The skills and knowledge targeted were not only those strictly referred to drawing as the instructional materials exhibited but also to the application in an uncontrolled and new online application of the concepts acquired. Thus, the task of drawing with vector graphics was set on a different software from the one used in the tutorial videos. 'Vctr' is a free, online application that shares the basic concepts and principles but presents a different layout, as many vector graphics editors share foundational concepts learning to use any of them can entail familiarity with all of them. Other tasks require certain critical knowledge about internet searches or software within the scope of the given instruction, testing the 'learning to learn' imprint left on the students and the previous skills and digital culture that can be assumed as common. The ability to find similar instructional materials and judge their adequacy is measured as a specific demonstration of high-order cognitive skills, file format knowledge and installation information were included as digital literacy signs of required cognitive skills for common internet use.

Measures

To classify participants into experiment and control groups a question opens the survey asking about the involvement with the provided instructional materials. Since classrooms are not laboratories and each participating teacher was free to apply the given materials as their classroom plan required, some of them making it mandatory to watch the screencasting videos at school while others using them as homework or elective work, the question designed to measure the involvement of the students had a gradation of possible answers. This was a multiple-choice question coded into the categorical variable **Participation** with the following values: 1 (students answering 'I don't know the videos', corresponding to those that didn't follow the screencasting videos and will then act as control group), 2 (students answering 'I have watched the videos on my own', 3 (when the answer was 'I have watched only some of them') and 4 (for the answer 'I have watched the videos with my teacher at school'). The question

from the surveys used to identify the level of involvement of the students in this experiment was also used to group the observations in the statistical analysis. Students with Participation value = i will be referred to as students in Group i.

The remaining answers to the surveys were coded into five categorical ordinal variables, with values increasing for better answers are as follows:

- **Installation** codes the answer to the question 'I have installed Inkscape in the computer I mostly use': students who answered that they had not were assigned value 0, while those answering yes were assigned 1.
- Free_software coded answers to the question 'An open software is' with three values: 0 (I don't know), 1 (Any software that costs no money) and 2 (Software that allows anybody to modify and share its code).
- Vector_editor variable coded answers to the question 'A vector graphics editor is' with three values: 1 (I don't know), 2 (A software to edit photos) and 3 (An application to draw using geometrical objects).
- **Tutorial** variable codes the answer to the request 'Go online and find a video tutorial in Spanish on how to use Inkscape that you find useful, paste the link to it here. If you are unable please explain what was the difficulty' with five possible values that were assigned after post-processing the answers one by one: 1 (non-sense or mischievous response), 2 (I don't know or similar answers), 3 (wrong link or technical difficulties stated by the students), 4 (link to a correct tutorial but created by the author of the supporting videos) and 5 (link to a correct tutorial not by the author of the supporting videos).
- Drawing variable codes the answer to the request 'Go online to https://vectr.com/ and make a drawing, export it and paste the link to it here. If you are unable to do so, explain the difficulty'. with five possible values that were assigned after post-processing the answers one by one: 0 (nonsense or mischievous response), 1 (I don't know or similar answers), 2 (link not working or similar technical difficulties), 3 (drawing correct but basic, making use of only one tool), 4 (drawing correct and complex, making use of more than one tool), 5 (drawing correct and outstanding, making use of many tools and achieving effect and composition).

Statistical models and procedures

The hypothesis that we are testing is that those students who followed the screencasting videos would improve their digital geometry skills and digital literacy, and consequently would be able to fulfil the requests from the survey better than those not following the screencasting videos. To evaluate this hypothesis, we separated the student surveys into four groups according to the **Participation** variable. The categorical type of our variables implies that their distribution will not be normally-distributed; the Kruskal–Wallis non-parametric statistical test was therefore used to evaluate whether there were reliable differences among the mean values of the samples in the four groups, with significance level set to p < 0.05. When significant differences were found, post hoc tests were used to determine which groups were different with pairwise comparisons adjusted appropriately for multiple comparisons and significant level set to p < 0.05. These statistical tests are described in 'Nonparametric statistics for the behavioural sciences (2nd ed.)' (Siegel and Castellan 1988). The statistical analysis of the data was carried out in R studio software version 1.1.463 with pgirmess v1.6.9 library for post hoc comparisons.

Results

Table 1 summarises the results for the five evaluated variables (Installation, Free_Software, Vector_Editor, Tutorial and Drawing). This table is shown to facilitate a detailed examination of the results for every variable and group. The bar plots in Figures 1 to 5 show the average values, with standard error bar, for every group. Kruskal–Wallis *p*-value is shown for every variable. Compact letter display has been used to show significant differences (p < 0.05) between groups after the post hoc test corrected for multiple comparisons, so differences between groups sharing the same letter are not significant.

The Installation variable (Figure 1) shows how students who watched the videos on their own (Group 2) are able to install the software on their computers, with a higher installation value compared with the remaining groups, a significant difference when compared with Group 1 (control group).

The question about Free Software was incorrectly answered by most students in Group 1 (Table 1 and Figure 2), while for the other groups more students answered correctly (Free_Software values 1 and 2). The difference between Groups 1 and 4 was statistically significant.

When students were asked about the definition of a Vector Editor, most of them answered incorrectly (values 1 and 2) for Group 1 (Table 1 and Figure 3), while the proportion of incorrect answers decreased for the remaining groups, with the maximum proportion of correct answers in Group 4. The difference between Groups 1 and 4 was statistically significant.

Regarding the question about finding a tutorial video online, most students, even those that did not follow the videos (Group 1), were able to provide a correct tutorial



Figure 1. Bar plot showing the average values for Installation variable, with standard error bar, for every participation group. Kruskal–Wallis p-value is shown top left (p = 0.0019). Compact letter display shows significant differences (p < 0.05) between Groups 1 and 2.



Figure 2. Bar plot showing the average values for Free_software variable, with standard error bar, for every participation group. Kruskal–Wallis *p*-value is shown top left (p = 0.017). Compact letter display shows significant differences (p < 0.05) between Groups 1 and 4.



Figure 3. Bar plot showing the average values for Vector_editor variable, with standard error bar, for every participation group. Kruskal–Wallis p-value is shown top left (p = 0.00018). Compact letter display shows significant differences (p < 0.05) between Groups 1 and 4.

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Figure 5. Bar plot showing the average values for Drawing variable, with standard error bar, for every participation group. Kruskal–Wallis *p*-value is shown top left (p = 1.2e-07). Compact letter display shows significant differences (p < 0.05) between Groups 1 and 4.

Table 1. Online survey data recollection.

	Value	Participation				Total
		1	2	3	4	_
Installation	0	48	3	29	59	139
	1	20	12	20	56	108
Free software	0	43	8	22	45	118
	1	14	2	15	33	64
	2	11	5	12	37	65
Vector editor	1	43	7	21	33	104
	2	4	1	5	13	23
	3	21	7	23	69	120
Tutorial	0	4	0	2	4	10
	1	11	1	1	2	15
	2	5	0	5	6	16
	3	10	0	9	37	56
	4	38	14	32	66	150
	0	11	1	2	3	17
	1	4	1	3	0	8
Drawing	2	7	2	9	11	29
	3	27	1	9	17	54
	4	18	10	23	72	123
	5	1	0	3	12	16
TOTAL		68	15	49	115	247
(per group)						

Number of responses for each variable in the survey. Each row corresponds to the specific variable value indicated in the first column. Second to fifth columns show the number of responses grouped by Participation value. Last columns recapitulate the total sum of responses for each variable value in all participation groups. Last row summarises the total number of responses for the group.

link (Table 1 and Figure 4). Consequently, no significant differences among groups were found according to Kruskal–Wallis test.

The Drawing variable encodes the responses when the students were asked to draw on their own with an online tool (Table 1 and Figure 5). Although many students in all groups were able to produce good quality drawings (value 4) or even outstanding ones (value 5), there is a significant difference between Groups 1 and 4, with increasing mean value from Groups 1 to 4.

Discussion and conclusion

The present research can be compared with similar initiatives from the recent past to draw general conclusions on the changes that have and have not taken place in technological adaptations for schools, using geometry teaching as a reference. Compared with the 'Development and classroom experimentation of interactive geometry exercises' published 30 years ago (Floris and Bevacqua 1989), we must agree that even though all scarcities mentioned then as detrimental factors have been overcome, change is still not taking place and we are still teaching paper and pencil-based geometry in one-third of all art class time throughout secondary school as the official curriculum in Madrid states. This reflects very poorly on how digital changes are taking place at schools and suggests that there is a lack of forces that drive such a change.

Online learning enables asynchronous access, reducing the temporal and spatial problems associated with traditional learning (Panigrahi, Srivastava, and Sharma 2018). It is no surprise to find student autonomy being enhanced by online methodology, as it is reinforced by the data, with a significant number of students characterising their participation as 'on their own', and installing the software on their computer. We can conclude that to the self-motivated online accessibility means increased autonomy. The significant group arising as having installed the software may point to those with previous knowledge and early-adopters family environments.

Concerning the digital readiness for online-based methodologies in this sample of Spanish schools, the results are clear: no significant technical issues were found and both teachers and students found resources in place enabling the use of the internet as a commodity. The schools and the teachers participating had the resources needed to participate, the students had the digital literacy and culture to use the internet, the screencast and vector graphic editors. From the Tutorial question results (Table 1, Figure 4), we can conclude that general online search and navigation are skills that have been previously acquired by all students. Taking into account the results of the Free_software and Vector_editor questions, we can also confirm both abstract definitions and understanding of tools were successfully transmitted in this context. There was no observable technological barrier as all tasks and questions were fulfilled, showing that both digital geometry and screencasting techniques are fully normalised for students. Most students both in the control and experiment group were able to draw with vector tools online.

Discussion now can centre on the fact that these ready-to-use, culturally-accepted, relevant technologies are still not being massively adopted by schools in their curriculums. The role institutions play and how changes take place are the next factors that need to be explored if we seek to better understand how to implement effective and meaningful change.

The absence of art as part of the digital literacy skillset (Bawden 2008), even when acknowledging the rising relevance of images as medium, as well as the absence of art in the data set and discourse of the OECD, may be signs of an inertial forces lingering around the arts. Further research on the phenomena would greatly add to the present discussion.

The pervasive use of vector graphics in the professional art industry is not a trend or a peak case of technology use. We have to address the need to teach these basic stepping stones of computer-enhanced geometry as part of our technological literacy criteria. Geometry as a subject should contain a radically different set of contents and skills in the digital age. We argue that arts are instrumental in the digital age and we can no longer postpone training our students. We encourage educational administrators to take account of the results and conclusions of the present research, which indicates a clear path for digital change through the arts in Spanish public schools.

References

- Bawden, D. (2008) 'Origins and concepts of digital literacy', in *Digital Literacies: Concepts, Policies and Practices*, eds C. Lankshear & M. Knobel, Peter Lang Publishing Inc, New York, NY, pp. 17–32.
- Brown-Sica, M., Sobel, K. & Pan, D. (2009) 'Learning for all: teaching students, faculty, and staff with screencasting', *Public Services Quarterly*, vol. 5, no. 2, pp. 81–97. doi: 10.1080/15228950902805282
- Buckingham, D. (2008) 'Defining digital literacy. What do young people need to know about digital media?', in *Digital Literacies: Concepts, Policies and Practices*, eds.C. Lankshear & M. Knobel, Peter Lang Publishing Inc, New York, NY, pp. 73–90.
- Carter, B. S., Hamilton, D. E. & Thompson, R. C. (2017) 'Learning experimental design through targeted student-centric journal club with screencasting', *Journal of Undergraduate Neuroscience Education*, vol. 16, no. 1, pp. A83–A88.
- Clements, D. H. & Battista, M. T. (1994) 'Computer environments for learning geometry', *Journal of Educational Computing Research*, vol. 10, no. 2, pp. 173–197. doi: 10.2190/8074-298A-KTL2-UQVW
- Decreto 48/2015, de 14 de mayo, del Consejo de Gobierno, por el que se establece para la Comunidad de Madrid el currículo de la Educación Secundaria Obligatoria., Boletín Oficial de la Comunidad de Madrid NUM118 10 (2015).
- Derex, M., et al., (2019) 'Causal understanding is not necessary for the improvement of culturally evolving technology', *Nature Human Behaviour*, vol. 3, no. 5, pp. 446–452. doi: 10.31234/OSF.IO/NM5SH
- Ergood, A., Padron, K. & Rebar, L. (2012) 'Making library screencast tutorials: factors and processes', *Internet Reference Services Quarterly*, vol. 17, no. 2, pp. 95–107. doi: 10.1080/1 0875301.2012.725705
- Ertsad, O. (2008) 'Trajectories of remixing. Digital literacies, media production, and schooling', in *Digital Literacies: Concepts, Policies and Practices*, eds C. Lankshear & M. Knobel, Peter Lang Publishing Inc, New York, NY, pp. 117–202.
- FitzGerald, E., et al., (2018) 'A literature synthesis of personalised technology-enhanced learning: what works and why', *Research in Learning Technology*, vol. 26. doi: 10.25304/rlt. v26.2095
- Floris, R. & Bevacqua, G. (1989) 'Development and classroom experimentation of interactive geometry exercises', *Journal of Computer Assisted Learning*, vol. 5, no. 3, pp. 161–176. doi: 10.1111/j.1365-2729.1989.tb00154.x
- Gilster, P. (1997) Digital literacy, Wiley Computer Pub, New York, NY.
- Green, K. R., Pinder-Grover, T. & Millunchick, J. M. (2012) 'Impact of screencast technology: connecting the perception of usefulness and the reality of performance', *Journal* of Engineering Education, vol. 101, no. 4, pp. 717–737. doi: 10.1002/j.2168-9830.2012. tb01126.x
- Iordanova, I. (2007) 'Teaching digital design exploration: form follows....', *International Journal of Architectural Computing*, vol. 5, no. 4, pp. 685–702. doi: 10.1260/147807707783600807
- Jensen, A. P. (2016) 'A technological, pedagogical, arts knowledge framework', Arts Education Policy Review, vol. 117, no. 3, pp. 153–158. doi: 10.1080/10632913.2016.1187970
- Johnson, G. M. (2008) 'Functional internet literacy: required cognitive skills with implications for instruction', in *Digital Literacies: Concepts, Policies and Practices*, eds C. Lankshear & M. Knobel, Peter Lang Publishing Inc, New York, NY, pp. 33–43.
- Kilickaya, F. (2016) 'Use of screencasting for delivering lectures and providing feedback in educational contexts: Issues and implications', in *CALL for openness*, eds M. Marczak & J. Krajka, Peter Lang, New York, NY, pp. 73–90. doi: 10.3726/978-3-653-06756-9
- Lloyd, S. A. & Robertson, C. L. (2012) 'Screencast tutorials enhance student learning of statistics', *Teaching of Psychology*, vol. 39, no. 1, pp. 67–71. doi: 10.1177/0098628311430640
- Logo Foundation. (n.d.) *Logo Foundation Publications*. Available at: http://el.media.mit.edu/ logo-foundation/resources/publications.html

- Loveless, T. (1996) 'Why aren't computers used more in schools?', *Educational Policy*, vol. 10, no. 4, pp. 448–467. doi: 10.1177/0895904896010004002
- Meyer, H.-D. (2014) 'Imagining PISA's policy futures: a postscript and some extensions to the open letter to andreas schleicher', *Policy Futures in Education*, vol. 12, no. 7, pp. 883–892. doi: 10.2304/pfie.2014.12.7.883
- Morris, C. & Chikwa, G. (2014) 'Screencasts: how effective are they and how do students engage with them?', *Active Learning in Higher Education*, vol. 15, no. 1, pp. 25–37. doi: 10.1177/1469787413514654
- Noss, R. (2013) 'Special Issue on knowledge transformation, design and technology', *Journal* of Computer Assisted Learning, vol. 29, no. 1, pp. 1–3. doi: 10.1111/j.1365-2729.2011. 00466.x
- OECD (2019), Students, Computers and Learning: Making the Connection, OECD Publishing, Paris, doi: 10.1787/9789264239555-en
- OECD (2011), PISA 2009 Results: Students on Line: Digital Technologies and Performance, PISA, OECD Publishing, Paris, Volume VI. doi: 10.1787/9789264112995-en.
- Panigrahi, R., Srivastava, P. R. & Sharma, D. (2018) 'Online learning: adoption, continuance, and learning outcome – a review of literature', *International Journal of Information Management*, vol. 43, pp. 1–14. Elsevier Ltd. doi: 10.1016/j.ijinfomgt.2018.05.005
- Papert, S. (1997) 'Why school reform is impossible', *Journal of the Learning Sciences*, vol. 6, no. 4, pp. 417–427. doi: 10.1207/s15327809jls0604_5
- Reimers, F. & McGinn, N. F. (1997) Informed Dialogue: Using Research to Shape Education Policy around the World, Praeger, Greenwood.
- Reynaud, E., et al., (2019) 'To watch is to work: a review of neuroimaging data on tool use observation network', *Neuropsychology Review*, vol. 29, no. 4, pp. 484–497. doi: 10.1007/ s11065-019-09418-3
- Rizvi, F. & Lingard, B. (2009) 'The OECD and global shifts in education policy', in *International Handbook of Comparative Education*, eds R. Cowen & A. M. Kazamias, Springer, Dordrecht, pp. 437–453. doi: 10.1007/978-1-4020-6403-6_28
- Sáez Lacave, A. (2018a) *Animación Gif Para 1º de la ESO*. YouTube. Available at: https://www. youtube.com/playlist?list=PLlbu8JYb436DUtFWcTOVomz4yBH5ER-qD
- Sáez Lacave, A. (2018b) *Red Geometrica Para 2^o ESO*. YouTube. Available at: https://www. youtube.com/playlist?list=PLlbu8JYb436Cscnhny2-ErwkDguhoATxq
- Schön, D. A. (1983) The Reflective Practitioner: How Professionals Think in Action, Basic Books, New York, NY.
- Siegel, S. & Castellan, N. J. (1988) *Nonparametric Statistics for the Behavioral Sciences*, 2nd edn, McGraw-Hill, New York, NY.
- Snyder, C., Paska, L. M. & Besozzi, D. (2014) 'Cast from the past: using screencasting in the social studies classroom', *The Social Studies*, vol. 105, no. 6, pp. 310–314. doi: 10.1080/00 377996.2014.951472
- Sugar, W., Brown, A. & Luterbach, K. (2010) 'Examining the anatomy of a screencast: uncovering common elements and instructional strategies', *The International Review* of *Research in Open and Distributed Learning*, vol. 11, no. 3, p. 1. doi: 10.19173/irrodl. v11i3.851
- Thomas, A. (2017) 'Screencasting to support effective teaching practices', *Teaching Children Mathematics*, vol. 23, no. 8, pp. 492–499. doi: 10.5951/teacchilmath.23.8.0492
- Walk, S. R. (2011) 'Improving technological literacy criteria development through quantitative technology forecasting', in *Proceedings of the 118th ASEE Annual Conference & Exposition*, ed ASEE, pp. 22.840.1–22.840.22.
- Walk, S. R. (2012) 'Quantitative technology forecasting techniques', in *Technological Change*, ed A. InTech, Rijeca, Croatia, pp. 103–124 [online]. Available at: http://www.intechopen. com/books/technological-change/quantitative-technology-forecasting-techniques
- Wilensky, U. & Papert, S. (2010) 'Restructurations: Reformulating knowledge disciplines through new representational forms', Paper presented at the Constructionism 2010, Paris,

France, [online]. Available at: https://pdfs.semanticscholar.org/a684/d3149266ce9e55dc-366b8acbbc6e905f8c80.pdf

- Zawacki-Richter, O. & Latchem, C. (2018) 'Exploring four decades of research in Computers & Education', *Computers & Education*, vol. 122, pp. 136–152. doi: 10.1016/j.compedu. 2018.04.001
- Zhang, D., et al., (2006) 'Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness', *Information & Management*, vol. 43, no. 1, pp. 15–27. doi: 10.1016/j.im.2005.01.004
- Zhao, Y. (2015) 'Who's afraid of PISA: the fallacy of international assessments of system performance', in *Leading Futures Global Perspectives on Educational Leadership*, eds M. S. Jones & A. Harris, SAGE Publications, Inc, Thousand Oaks, CA, pp. 7–21.
- Zhao, Y. & Frank, K. A. (2003) 'Factors affecting technology uses in schools: an ecological perspective', *American Educational Research Journal*, vol. 40, no. 4, pp. 807–840. doi: 10.3102/00028312040004807